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Emission factors affecting soil NH_3 losses from mineral fertilizers

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The review focuses on soil-derived NH_3 emissions from mineral fertilizer and the main factors influencing applied N losses.

Ammonia (NH_3) emissions from agricultural soil has been a concern and principal investigative issue, especially in slurry/manure use and management practices. The amount of soil N loss due to NH_3 volatilization varies depending on soil conditions, fertilizer, fertilization method, climate, etc. Ma *et al* (2020) reported that average global NH_3 emissions from synthetic N fertilizer is about 13%, with Europe contributing 7.1% of total global NH_3 emissions. This review focuses on soil-derived NH_3 emissions from mineral fertilizer and the main factors influencing applied N losses, which is less represented in recent literature. Most literature found focuses on NH_3 emissions from urea fertilizer and applied urea with an inhibitor. Details from all articles and results discussed in this review, can be viewed in the link below.

Overall, the results from numerous articles conclude that surface broadcast application of 100 kg N ha^{-1} urea resulted in NH_3 losses ranging from 3-39% and from 8-68% when 130 kg N ha^{-1} was applied. Additionally, they found that 150 and 180 kg N ha^{-1} urea applied at pre-sowing resulted in 13.7% and 9.7% NH_3 loss, compared to only a 1.3% and 6.8% loss when urea was applied 200 and 160 kg N ha^{-1} topdressing. On clay loam soil, NH_3 volatilization was reduced by 34% when urea was incorporated compared to left on the surface (Woodley et al., 2020). Riva *et al* (2016) concluded that sub-surface injection allowed NH_3 emissions to be reduced by 69% and 77% compared with surface application in soil with a high sand content. Urea ammonium nitrate (UAN) injected at a rate of 130 kg N ha^{-1} resulted in 8-31% NH_3 loss. Furthermore, a significant reduction in loss was also found after injecting 150 kg N ha^{-1} UAN compared to surface broadcast of urea, 0.27% and 14.2% (Woodley et al., 2020).

Several articles conclude that the broadcast application of urea fertilizer resulted in the highest NH_3-N percentage loss of applied N compared to DAP, CAN and AS (Sommer and Jensen, 1994; Velthof et al., 1990; Van der Weerden and Jarvis, 1997; Botha and Pretorius, 1988; Sommer et al., 2004). Rouchette *et al* (2009) found that NH_3 loss from surface broadcast of 14 g N m^{-2} urea in no-till plots were significantly higher compared to moldboard plowed plots in clay loam (25% and 4%), heavy clay (20% and 2%), and silty clay loam soil (19% and 5%).

When comparing articles, the variations in location, thus a difference in soil texture, soil moisture content and pH, affected NH_3 losses from applied N. In an article by Turner *et al* (2016), the experimental site with higher rainfall had greater NH_3 loss. This conclusion is consistent with a study by Bouwmeester et al (1985), which suggests that reduced NH_3 volatilization rates resulted from a lack of soil moisture restricting urea dissolution and urea hydrolysis. Soil pH can increase after urea has been hydrolyzed to bicarbonate and ammonium (Black et al., 1985; White and Raistrick, 1990), which occurred in Sommer and Jensen (1994), where a high pH caused a loss of 18 to 30% of applied urea and DAP. Sommer and Jensen (1994) found low NH_3 losses from AS and CAN in all experiments, which may be due to AS and CAN not significantly changing soil pH. Furthermore, they explain that ammonia loss rate declines over time because the ammonia concentration in the soil declines due to the loss of ammonia and reduction in pH and nitrification. Figure 1 is from Rochette *et al* (2009)'s study, where they concluded that, since the initial urease activity at L'Acadie was not greater than at the other two sites, the higher volatilization was likely the result of a higher soil pH at L'Acadie. The positive correlation between soil pH and NH_3 loss is also represented in Appendix, figure 1d.

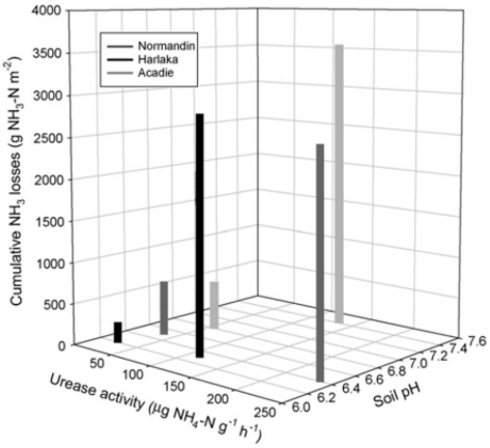

Figure 1. Relationships between cumulative NH_3 emissions and soil urease activity and pH in the top 1 cm of no-till (solid bars) and moldboard plowed (broken bars) soils from three long-term experiments in Quebec, Canada (Rochette et al., 2009).

Treatments with an applied N-inhibitor in combination with urea resulted in a significantly lower percentage of NH_3 loss. In an article by Abalos *et al* (2012), NH_3 emissions were lowered by 58% in the treatment with 120 kg N ha^{-1} urea applied with 20% N-(n-butyl) thiophosphoric triamide (NBPT) inhibitor. Spring barley yield in this experiment was greater in the urea+NBPT treatment compared to the treatment with 120 kg N ha^{-1} untreated urea. This is consistent with a field study by Engel *et al* (2011), where they concluded that 100 kg N ha^{-1} of applied urea coated with NBPT (1 g kg^{-1}) reduced cumulative NH_3 losses by 66% (Figure 2). Volatilization protection lasted 2 to 3 weeks on acidic soils and more than 7 weeks on an alkaline soil (Engel et al., 2011). In this case, the urease inhibitor NBPT to urea significantly reduced NH_3 loss in all trials compared to untreated urea, which is especially evident in Figure 2a (Campaign 3), where the reduction in total cumulative loss by NBPT was about 88% because emissions for the campaign mostly confined to the first 14-20 days after fertilization.

NH_3 emissions are also influenced by air temperature, wind speed and the amount of rainfall or irrigation (Ahmed et al., 2018; Engel et al., 2011; Turner et al., 2012; Grant et al., 1996). Ahmed *et al* (2018) found that at two of their experimental sites, Zhouzhi-1 and Zhouzhi-2, rainfall events influenced the highest emission rate and sequential reduction of NH_3 volatilization, which may be due to rainfall dispersing urea into the soil. Figure 2 shows the results from Engel *et al* (2011)'s experiments, with time-integrated NH_3 flux from urea and N-(n-butyl) thiophosphoric triamide (NBPT)-coated urea, soil temperature (at 1-cm depth), and daily precipitation amounts during Campaigns (a) 3 and (b) 4 conducted on sandy loam (pH 5.5) and (c) Campaign 5 conducted on loam (pH 6.4). After urea was applied to high-water-content soil surfaces, there was a 30-44% loss of applied N. There were high NH_3 losses from acidic and alkaline soils, therefore, Engel *et al* (2011) concludes that the impact of soil water conditions at the time of urea fertilization, and the magnitude of precipitation that followed, were more impactful than soil pH in defining NH_3 loss potential.

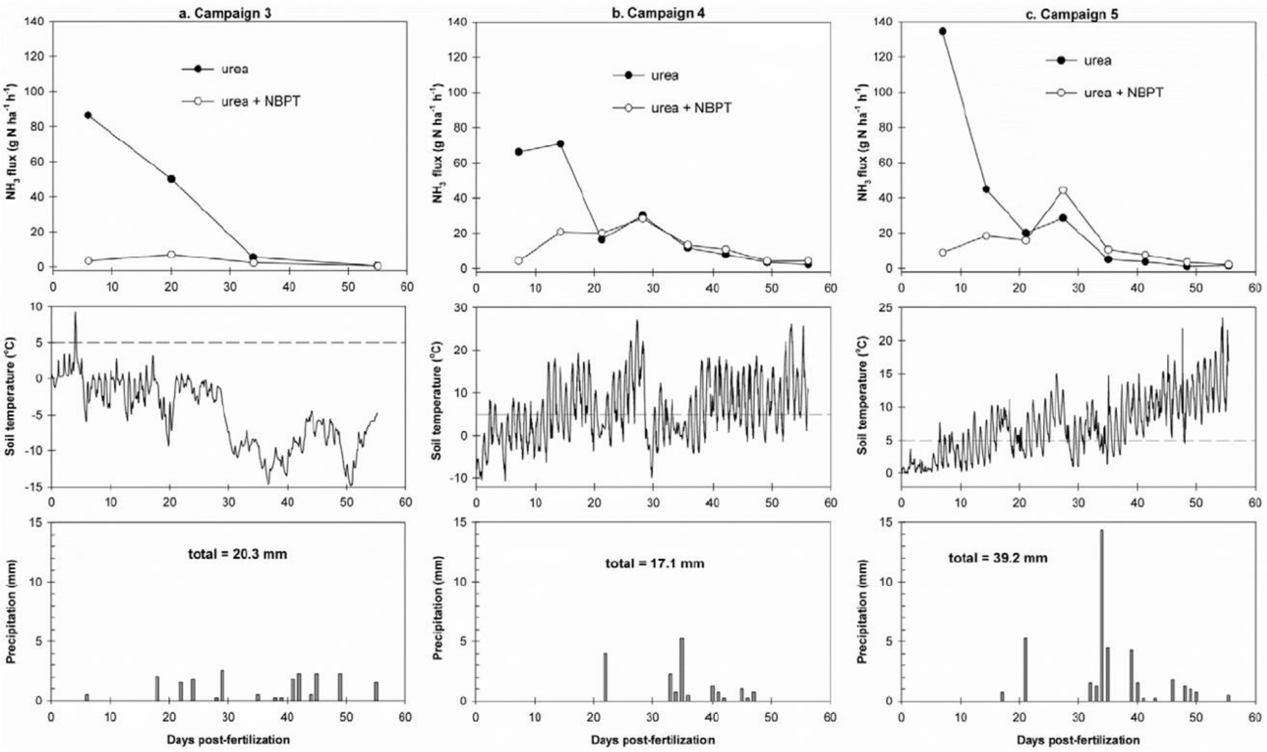

Figure 2. Time-integrated NH3 flux from urea and N-(*n*-butyl) thiophosphoric triamide (NBPT)-coated urea, soil temperature (at 1-cm depth), and daily precipitation amounts during Campaigns (a) 3 and (b) 4 conducted on a Telstad-Joplin sandy loam (pH 5.5) and (c) Campaign 5 conducted on a Phillips-Elloam loam (pH 6.4) (Engel et al., 2011).

Furthermore, Turner *et al* (2012) suggests that rainfall after fertilizer application had an impact on NH_3 losses. This is consistent with Sommer *et al* (2004), where they note that very dry conditions delayed NH_3 emissions. Grant *et al* (1996) attributes greater NH_3 losses to higher soil and air temperatures and lower initial soil moisture levels in August compared to May. Ma *et al* (2020) shows a positive but weak relationship between soil NH_3 fluxes and mean annual precipitation, (shown in the appendix, figures 1a and 1g), as well as a weak correlation between soil NH_3 fluxes and soil temperature, (shown in the appendix figures 1b and 1h).

Conclusion

In this review, there was a lack of recent literature found regarding soil-derived NH_3 emissions from mineral fertilizer and the main factors influencing applied N losses. Most of the literature found focused on NH_3 emissions from urea fertilizer and applied urea fertilizer with an inhibitor. NH_3 emissions vary depending on soil conditions, fertilizer, fertilization method and climate. Ammonia loss is usually high after fertilizer application and rates decline over time as the ammonia concentration in the soil declines due to the loss of ammonia and reduction in pH and nitrification. According to a review by Ma *et al* (2020), soil NH_3 emissions are the most positively correlated with the application rates of N fertilizer and soil pH (*Figure 1e and 1d* in appendix)). Application of a N-inhibitor in combination with urea results in a significantly lower percentage of NH_3 loss. The use of an N-inhibitor can delay volatilization by 2 to 3 weeks on acidic soils, and more than 7 weeks on an alkaline soil.

>>Review on literature found regarding soil-derived NH3 emissions from mineral fertilizer

Appendix

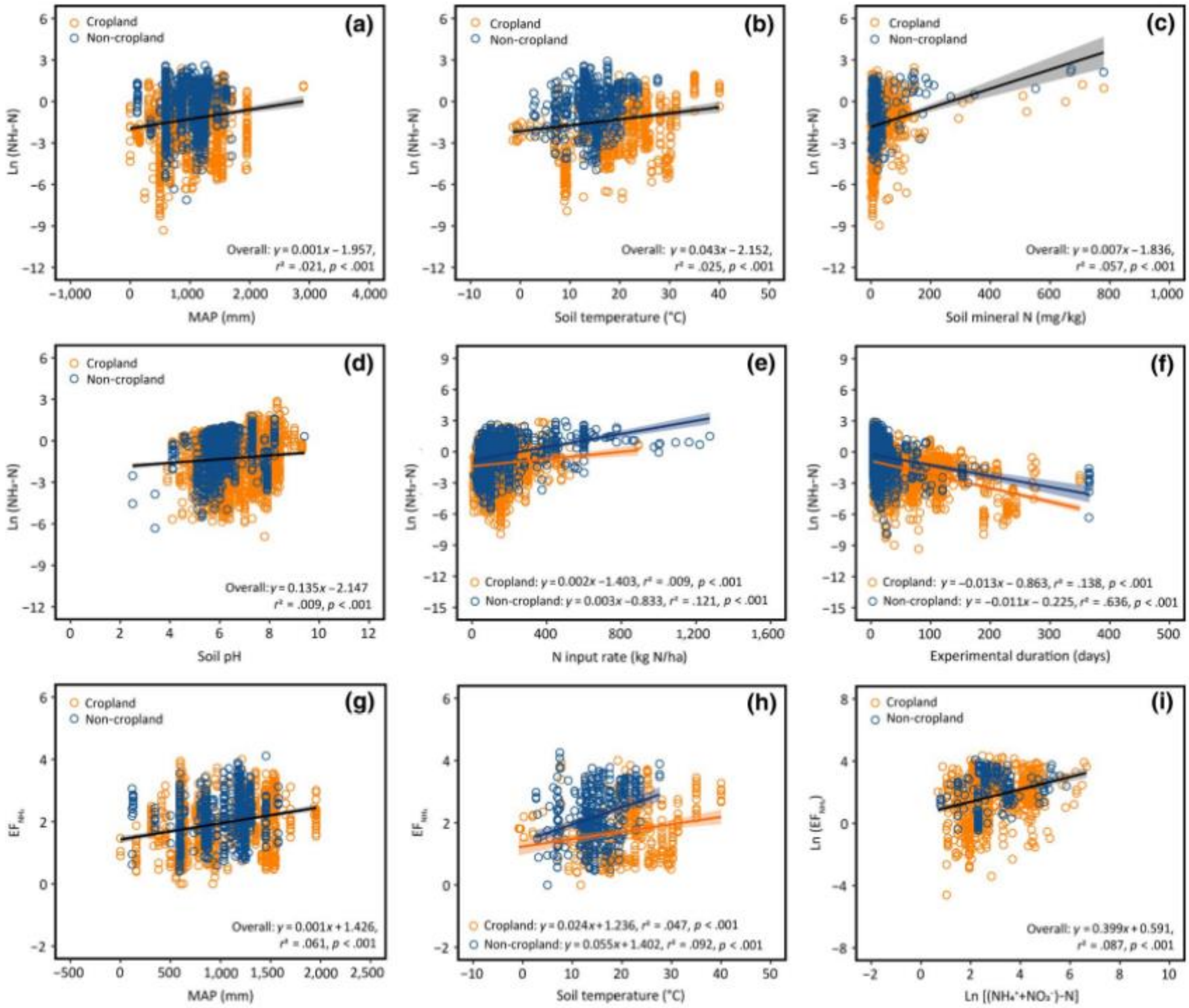

Figure 1a-i. Dependence of soil NH_3 fluxes and direct emission factors of N fertilizer for NH_3 (EFs) on soil, environmental, and experimental controls partitioned by agricultural and non-agricultural soils. Mean annual precipitation (a and g), soil temperature (b and h), soil mineral nitrogen (c and i) of the 0-20 soil depth, soil pH (d), N input rate (e), and experimental duration (f). (Ma et al., 2020).

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